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Cleaner bioprocesses for promoting zero-emission biofuels production in Vojvodina

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ABSTRACT

In this study, the policy, market conditions and food security of biomass energy sources are assessed for supplying the future needs of Vojvodina. The Autonomous Province of Vojvodina is an autonomous province in Serbia, containing about 27% of its total population according to the 2002 Census. It is located in the northern part of the country, in the Pannonia plain, in southeastern Europe. Vojvodina is an energy-deficient province. The incentives to invest human and financial resources in the research and development of cleaner bioprocesses are high, considering the benefits which might be achieved in terms of environment protection and manufacturing costs. In the near and medium tenu, the development of bioprocesses for waste recycling and resource recovery might be one of the most viable options, considering much research work has already been done. In Vojvodina, there are technological solutions that biofuels produced in a closed cycle, so that the quantity of waste reduced to a minimum. These solutions include the stillage (remainder after distillation) used for fattening cattle, and cattle excrement to produce biogas and manure as fertilizer. The energy required for the production of bioethanol is obtained combustion lignocelullose residual waste from the production of basic raw materials starch, or biogas. Ash from the burned biomass returned to soil as a source of minerals for plants and replacement of mineral fertilizer. Such a closed cycle is economical for small farms in Vojvodina.

Contents

1. Introduction

The Autonomous Province of Vojvodina is an autonomous province in Serbia, containing about 27% of its total population according to the 2002 Census. It is located in the northern part of the country, in the Pannonia plain. Vojvodina is an energy-deficient province. The indigenous reserves of oil and gas are limited and the country is heavily dependent on the import of oil. The oil import bill is a serious strain on the country's economy and has been deteriorating the balance of payment situation. The country has become increasingly more dependent on fossil fuels and its energetic security hangs on the fragile supply of imported oil that is subject to disruptions and price volatility [1–4]. Hydropower, biomass, biogas, biofuels, wind power, solar energy and geothermal energy are the major resources to provide Vojvodina with most of its renewable energy in the future [5–9].

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Proponents of biotechnology claim that it offers a wide range of environmental benefits. In the most extreme case this could mean the development of the perfect crop: seeds that require reduced or nil pesticides or herbicides; reduced water and soil, and produce crops with higher nutritional benefits which, in some cases, ripen just in time to be bought to reduce wastage. Indeed, this appears to be a perfect example of a cleaner production application [10]. On the other hand, biotechnology opponents claim that it will:

- Decrease gene pools making diseases more devastating;
- Facilitate the transfer of genetically modified genes to wild species which could radically damage ecosystems;
- Lead to a general dependence on capital and technology intensive agricultural systems.

The concept of "cleaner technology" has been defined by the Organisation for Economic Cooperation and Development (OECD) as: "...technologies that extract and use natural resources as efficiently as possible; that generate products with reduced or no potentially harmful components in all stages of their lives; that minimize releases to air, water and soil during fabrication and use of the product; that produce durable products which can be recovered or recycled as far as possible; and are energy efficient." [11].

What the technology will eventually offer lies somewhere between these two extremes. We begin this report with a brief discussion of the cleaner production approach.

2. The cleaner production approach

The traditional approach to environmental management has been reactive pollution control approaches, while progressive companies have recently adopted proactive pollution prevention strategies. Preventative strategies include Industrial Ecology, Ecologically Conscious Management, Life Cycle Analysis, Design for the Environment, Dematerialization, Design for Efficient Longevity, and Sustainable Product Development among others [10].

A main objective of proactive strategies is the development of clean technologies, defined by The Commission of the European Communities as "any technical measures taken at various industries to reduce or even eliminate at source the production of any nuisance, pollution or waste, and to help save raw materials, natural resources and energy". The more philosophical cleaner production approach is defined by Huisingh to be "An ongoing process involving technical as well as attitudinal, motivational and other non-technical factors that are essential for corporations to benefit from the preventative approach." Baas et al. argue that cleaner production is philosophically and methodologically grounded, stating that it is: "The conceptual and procedural approach to production that demands that all phases of the life-cycle of a product or of a process should be addressed with the objective of prevention or the minimization of short and long term risks to humans and the environment" [10].

Ultimately the objective of proactive approaches is to achieve sustainable production capabilities, where (for the purpose of this discussion) environmental and economic systems are in balance. Baas states that cleaner production is an effective approach to understanding the "best ways of fostering the development of a paradigm shift toward sustainable production and service organizations and products". As such, it could be argued that biotechnology offers cleaner production opportunities if environmental implications are considered, which in turn can lead to more sustainable forms of production. However, it will be shown that this is very much dependent upon the technological trajectory followed. A number of authors claim that environmental issues are becoming increasingly important in the decision making process of firms [10]. This is generally influenced by pressures from customers, environmental activists, shareholders, government regulatory agencies and community groups. We argue that environmental issues are especially relevant for agricultural biotechnology firms, as they can potentially offer both environmental risks and benefits.

3. Cleaner bioprocesses

Two of the premises of sustainable development are that economic growth has to be in harmony with the environment and that a rational and sustainable use of natural resources has to be implemented. In congruence with such premises, industrial development has to change from the degradative to the sustainable style. To meet such a purpose, adoption of cleaner production systems is essential.

The United Nations Environment Programme (UNEP) defines the cleaner production concept as "the continuous application of an integrated preventive environmental strategy to processes, products and services to increase eco-efficiency and reduce risks to humans and the environment". One of its distinctive features is that reduction of the quantity and toxicity of all emissions and wastes is made before they leave the process stream. Also, the entire life cycle of the product, from raw material extraction to the ultimate disposal of the product, is evaluated to reduce negative impacts. In the case of services, environmental concerns should be incorporated into design and delivery.

Eco-efficiency is a concept promoted by the Business Council for Sustainable Development. It involves "the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life while progressively reducing ecological impacts and resource intensity, throughout the life cycle, to a level at least in line with the Earth's estimated capacity".

The cleaner production strategy may be implemented through a sequential path (Fig. 1) according to the specific needs and availability of funds, always within an integrated approach.

It is clear that adoption of clean production systems by industries calls for fundamental changes, not only at the technological level but also at the legislational level. Innovation and adoption of clean technologies should be a paramount target of research and development groups world-wide. Accordingly, new incentives and policies should be promoted in the near future [12].

Although new regulation systems will be required to accelerate the adoption of cleaner technologies, the striking feature of this movement is that industries are expected to adopt them

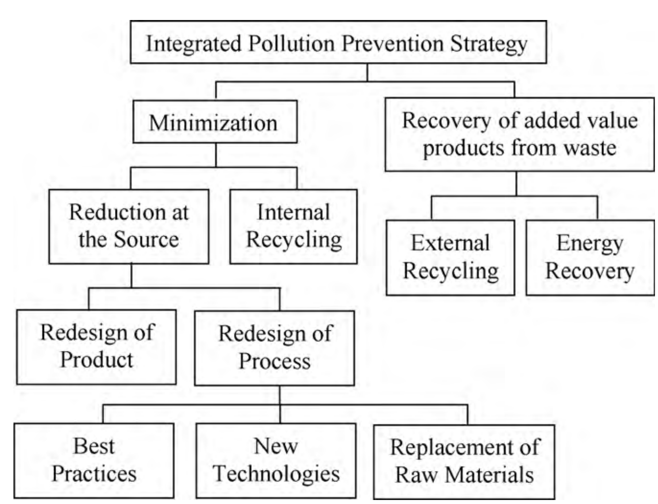

Fig. 1. Different actions for the implementation of the cleaner production strategy.

voluntarily, moved by the motivation of considerable savings in water, energy and other inputs, as well as in savings in pollution control costs. Such is the case of some processes like the "wet process" for coffee depulping and demucilagination, in which the introduction of new equipment that does not require water gives considerable savings in water cost and wastewater treatment.

Cleaner bioprocesses are under intensive research and development following the general guidelines for cleaner production. The most common approach has been to use enzymes as substitutes for chemical catalysts, and enzyme applications have been introduced in the textile industry (for bio-stonewashing of jeans), in the leather and tanning industry (for degreasing hides), in the food industry (for production of instant coffee, among other products) and in pulp and paper bleaching. Significant reduction or complete elimination of harsh chemicals may be achieved and the cost of production reduced by saving water and energy.

The use of enzymes in the animal feed industry to improve digestibility of raw material, mainly cereals, results in several relevant benefits: saving in the cost of raw material, significant reduction in waste volume and reduction in the nitrogen and phosphorus content of the waste. The use of enzymes in the food industry allows the replacement of acid for starch hydrolysis, with concomitant reduction in energy consumption and aggressive chemicals in the wastewater. In beer production the benefits from using enzymes are manifold and lower the cost of production.

Another approach to clean production is the generation of new and cleaner products such as bio-insecticides, for example the production of *Bacillus thuringiensis* as a source of potent insecticide crystals.

The incentives to invest human and financial resources in the research and development of cleaner bioprocesses are high, considering the benefits which might be achieved in terms of environment protection and manufacturing costs. In the near and medium tenu, the development of bioprocesses for waste recycling and resource recovery might be one of the most viable options, considering much research work has already been done [12].

4. Global biofuels scenarios

Renewable resources are more evenly distributed than fossil and nuclear resources, and energy flows from renewable resources are more than three orders of magnitude higher than current global energy use. Today's energy system is unsustainable because of equity issues as well as environmental, economic, and geopolitical concerns that have implications far into the future [13]. According to International Energy Agency (IEA), scenarios developed for the USA and the EU indicate that near-term targets of up to 6% displacement of petroleum fuels with biofuels appear feasible using conventional biofuels, given available cropland. A 5% displacement of gasoline in the EU requires about 5% of available cropland to produce ethanol while in the USA 8% is required. A 5% displacement of diesel requires 13% of USA cropland, 15% in the EU [13]. The dwindling fossil fuel sources and the increasing dependency of the USA on imported crude oil have led to a major interest in expanding the use of bio-energy. The recent commitment by the USA government to increase bio-energy 3-fold in 10 years has added impetus to the search for viable biofuels. The EU have also adopted a proposal for a directive on the promotion of the use of biofuels with measures ensuring that biofuels account for at least 2% of the market for gasoline and diesel sold as transport fuel by the end of 2005, increasing in stages to a minimum of 5.75% by the end of 2010 [13]. Fig. 2 shows main biomass conversion processes. Fig. 3 shows resources of main liquid biofuels for automotives. Table 1 shows the shares of alternative fuels compared to the total automotive fuel consumption in the world as a futuristic view.

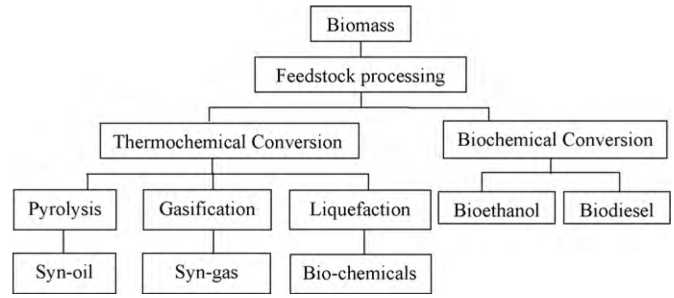

Fig. 2. Main biomass conversion processes.

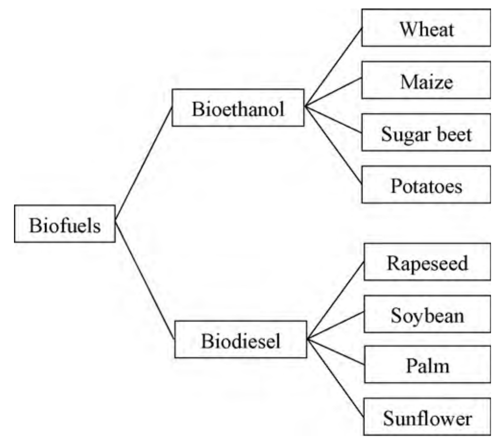

Fig. 3. Resources of main liquid biofuels for automotives.

5. Bioethanol production from feedstocks

Rising demand for liquid transportation fuels and diminishing supplies of crude oil will continue to create substantial market forces. These pressures, along with concerns about energy security, inflation induced by energy prices, domestic agricultural policies and climate control, will lead to continuing interest in conventional sugar- and starch-crop-based motor-fuel-grade bioethanol. Today, the majority of the world's bioethanol is produced from sugar cane and maize, each supplying nearly equal volumes of fuel bioethanol. Since the early 1980s, the growth in bioethanol production has been primarily driven by agricultural, environmental and energy policies implemented by Brazil and the United States.

As global economies continue to improve, the demand for transportation fuels will increase, and countries will develop policies that promote renewable fuels and develop domestic

Table 1
Shares of alternative fuels compared to the total automotive fuel consumption in the world.

Years	Alternative fuel consumption (%)		
	Biofuels	Natural gas	Hydrogen
2005	1.2	0.2	0.1
2010	3.0	1.0	0.4
2015	4.8	1.4	1.4
2020	6.0	6.4	4.0
2025	7.0	8.2	7.0
2030	8.4	9.6	10.0
2035	10.0	10.0	12.8
2040	11.0	9.2	15.0
2045	12.0	8.0	17.0
2050	12.4	7.8	18.0

production capacities for bioethanol. These "first-generation" facilities will continue to utilise readily available agricultural commodities and existing technologies until "second-generation", lignocellulosic-based ethanol processes are commercially available. Even then, it is unlikely that second-generation feedstocks and technologies will supplant first-generation production because of the significant demand that bioethanol is placing on global agricultural commodity markets.

Agricultural statistics show global sugar and starch crop production approaching 2500 million tonnes per year. Feedstock selection continues to be heavily influenced by cultural, agricultural, geographic, climatic and policy issues. Generally, bioethanol production facilities are designed to utilise readily available domestic feedstocks. In Brazil and the US, the feedstocks of choice have been sugar cane and maize, respectively [14]. As the industry expands to new regions, alternative feedstocks will be used to a greater extent.

As the bioethanol industry continues to develop, producers look to secure ample supplies of cost-effective, regionally available feedstocks. The primary crops currently being used or considered for bioethanol production can be categorised by agricultural and process-related properties. The concentration of fermentable carbohydrates and other parameters key to the use of the feedstocks in bioethanol production are highly variable.

Global economies will continue to increase the demand for personal transportation and associated liquid fuels into the foreseeable future. These demands, along with concerns about the impact of fossil fuels on our environment, necessitate finding alternate renewable energy sources. Rapid growth in the demand for fuel ethanol was partially responsible for higher commodity prices during 2007 and 2008. This was one of the few times in history that demand, and not supply, was the driving force in commodity pricing.

Historically, the demand for agricultural commodities has increased gradually in response to global population growth, and spikes in price have been the result of crop failures or misguided policies. Expected price increases related to this slow increase in demand have been suppressed by policy and by improved fanning practises. In short, farming practises have been controlled by governmental policies for the past century. Agricultural technology development has been driven by market forces calling for the production of nearly fixed volumes of commodities at the lowest possible cost. Revolutionary improvements in agriculture found no market in an arena of acreage allotments.

Biofuels have created a new and expanding market. Recent growth in this industry has outpaced the agricultural industry's capability to meet the demand for feedstocks. Today, the major sugar and starch crops have the potential to produce approximately 986 million cubic metres of fuel bioethanol per year, with a fuel value equivalent of 11.3 million barrels of gasoline per day.

Improvements in farming practises and advancements in plant genetics promise to deliver dramatic improvements in crop productivity. The opportunity exists for the agricultural industry to make a significant contribution to the world's liquid transportation fuel needs as well as meeting the global demand for food [15].

6. Cleaner biofuels production

There are technological solutions that biofuels produced in a closed cycle, so that the quantity of waste reduced to a minimum.

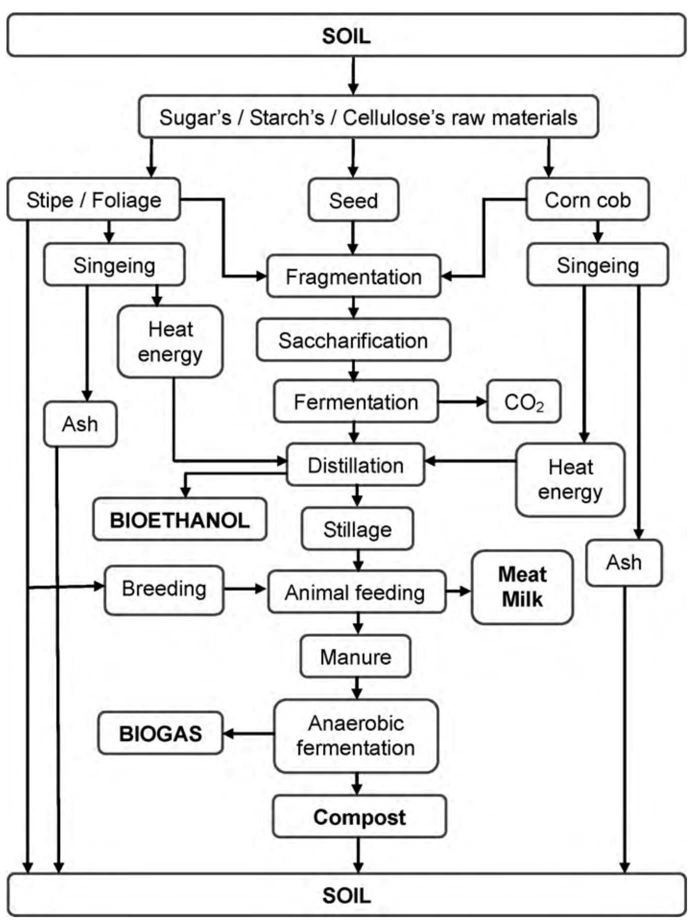

Fig. 4. Cleaner biofuels production on farms.

These solutions include the stillage (remainder after distillation) used for fattening cattle, and cattle excrement to produce biogas and manure as fertilizer. The energy required for the production of bioethanol is obtained combustion lignocelullose residual waste from the production of basic raw materials starch, or biogas. Ash from the burned biomass returned to soil as a source of minerals for plants and replacement of mineral fertilizer. Such a closed cycle is economical for small farms in Vojvodina [16]. Schematic representation of this process shown in Fig. 4.

7. Conclusions

It is clear that adoption of clean production systems by industries calls for fundamental changes, not only at the technological level but also at the legislational level. Innovation and adoption of clean technologies should be a paramount target of research and development groups world-wide. Accordingly, new incentives and policies should be promoted in the near future. As the bioethanol industry continues to develop, producers look to secure ample supplies of cost-effective, regionally available feedstocks. The primary crops currently being used or considered for bioethanol production can be categorised by agricultural and process-related properties. The concentration of fermentable carbohydrates and other parameters key to the use of the feedstocks in bioethanol production are highly variable. Biofuels have created a new and expanding market. Recent growth in this industry has outpaced the agricultural industry's capability to meet the demand for feedstocks. There are technological solutions that biofuels produced in a closed cycle, so that the quantity of waste reduced to a minimum. These solutions include the stillage (remainder after distillation) used for fattening cattle, and cattle excrement to produce biogas and manure as fertilizer. The energy required for the production of bioethanol is obtained combustion lignocelullose residual waste from the production of basic raw materials starch, or biogas. Ash from the burned biomass returned to soil as a source of minerals for plants and replacement of mineral fertilizer. Such a closed cycle is economical for small farms in Vojvodina.

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